UNIVERSITY OF CALIFORNIA PUBLICATIONS

COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
BERKELEY, CALIFORNIA

# MONILIA BLOSSOM BLIGHT (BROWN ROT) OF APRICOTS

BY

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BULLETIN No. 383

FEBRUARY, 1925

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UNIVERSITY OF CALIFORNIA PRINTING OFFICE
BERKELEY, CALIFORNIA
1925

# MONILIA BLOSSOM BLIGHT (BROWN ROT) OF APRICOTS*

By B. A. RUDOLPH

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* The term *Monilia* blossom blight is suggested for adoption as a common name for the blossom and the twig blight phase of the disease to distinguish it from "Brown Rot," a decay of the ripening fruit, produced by the same organism. The term brown rot is so universally used elsewhere to designate the rot of the fruit that its use in California to designate the disease of the blossoms and twigs is very confusing.

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## SUMMARY

Monilia blossom blight is due to the attack of a fungus of the genus *Sclerotinia*. The fungus reproduces itself by means of spores which are produced in abundance, before the blossoms open, on the old blighted twigs and decayed fruits left in the trees. A second reproductive form is known, but it rarely occurs in California.

The blossoms may be attacked at any time after the buds have cracked and show the folded white petals beneath the red sepals, until the full bloom or even a little later when the petals have been shed. Having killed a blossom the fungus passes into the twig and kills it. Later the fungus attacks the ripening fruit producing a characteristic "brown rot."

The disease was first described in Europe in 1796, in America in 1881, and it was known to exist in California before 1900.

The disease has become exceedingly destructive in California in recent years. This is possibly due to the planting of less resistant varieties.

Over one hundred different treatments, involving the use of most of the better known fungicides, oil emulsions, coal-tar derivative sprays, fungicidal dusts and various proprietary preparations presumably possessing fungicidal properties, have been tried out experimentally during the past four years for the control of the disease. These materials were used separately or in combination, in single or multiple applications at various times either before, during or after the bloom. In addition to these experiments, records of the methods employed and the control obtained in approximately two hundred private orchards were compiled. From the data accumulated it has been concluded that:

(1) In orchards already seriously infected and situated in localities where normal climatic conditions render the disease difficult to control, a dormant spray of any standard fungicide may decrease the amount of disease noticeably, but seldom sufficiently to be of practical value.

(2) A spray applied in the spring when the buds are expanding, or still later in the red bud stage, affords the best control obtainable with any one spray. Frequently such a spray controls the disease. In orchards situated in localities normally damp during the susceptible period and where little effort has been made to remove the great accumulation of old infectious material from the trees, the control obtained by such a spray may be entirely unsatisfactory, although, relatively speaking, the amount of disease may be much diminished.

(3) The more closely the application of the spray approximates the period when the buds are cracking, showing the folded white petals beneath the red sepals, the greater the control is apt to be, but there is no certainty that, even at this favorable period, one application of any fungicide will give a practical control of the disease under adverse conditions. Relatively speaking, the control will be greater at this time than at any other, but from the practical standpoint, it is likely to be a failure.

(4) A spray applied at any time after the blossoms are open usually affords some relief, but from the practical standpoint, the control afforded generally is a failure, and, the longer the spray is delayed, the greater the failure is likely to be. Similarly, a full bloom spray usually affords some relief, but the results are invariably very unsatisfactory from the practical standpoint and particularly so if the susceptible period is damp.

(5) All sprays may help a little regardless of the time of application.

(6) Regardless of whether or not the trees have been sprayed, there will be little or no disease even though the fungous spores are present in the greatest abundance, unless rain, heavy dew or fog occurs during the susceptible period. Moisture is the great determining factor in the infection of the flowers. Many growers not recognizing this fact credit the control of the disease in dry seasons to weak mixtures of standard fungicides or to other spray materials which under more normal conditions prove utterly unsuited to the purpose.

(7) In badly diseased orchards situated in localities which are favorable to the ready development of the disease because the weather is normally humid during the blossoming period, and in cases where little or no attempt has been made to remove the great accumulation of old infectious material from the trees, multiple spraying throughout the entire susceptible period is the only means likely to secure a practical control. With this method several sprays are applied, starting with the red bud spray and following with others in quick succession as the flowers continue to open until the trees have reached full bloom, or even a little later when the petals have been shed.

(8) The degree of control in badly diseased orchards is proportionate to the number of sprays applied during the susceptible period of the blossoms.

(9) Orchard sanitation (the careful removal of all infectious material from the trees and the ground) is as vital as spraying in the control of the disease, but should be regarded as an auxiliary to spraying operations, rather than as a separate means of controlling the disease.

(10) The extent of the control by sprays is largely affected by the degree to which orchard sanitation has been observed.

(11) Manures, decaying and freshly cut grasses and alfalfa in the orchard do not harbor the fungus over winter. Many ornamental plants were examined, but the disease was found only in the Japanese quince (*Chaenomales japonica*).

(12) The fungicide best adapted to use on apricot trees and for the control of the disease is home-made Bordeaux 8–8–50. Bordeaux 5–5–50 or 6–6–50 frequently gives excellent results in orchards less severely affected or situated in localities where climatic conditions are more favorable to the control.

(13) Bordeaux does not interfere with the fertilization of the apricot blossoms whatever the time of application, fertilization apparently taking place before the red buds open.

(14) Having brought the disease within the limits of practical control by the multiple spray method, fewer sprays, and in most instances, only one spray of Bordeaux 8–8–50 or weaker strength will be needed in succeeding years to hold the disease in check.

(15) Lime-Sulfur, Soda-Sulfur and other sulfur-containing compounds are distinctly unsuited for use on apricots because they cause a physiological injury to the trees commonly referred to as "sulfur poisoning." The foliage on such trees is stunted and yellowish, the fruit is dwarfed, of poor color and quality, and ripens late. Even pure sulfur applied with water to the ripening fruit may cause it to be stunted and late in ripening. Apricot trees treated with sulfur or sulfur-containing compounds sometimes fail to bloom the following season.

(16) The more commonly used oil emulsions, miscible oils and coal-tar derivative sprays which are applied in winter for the control of insect pests have some fungicidal effect, but insufficient for the control of the disease in badly diseased orchards in humid localities. The relative degree of control they afford is sometimes quite marked, but from the practical standpoint they are generally unsatisfactory. Applied in the spring they usually burn the buds or lower the crop yield by interfering with the pollination of the flowers.

(17) Fungicidal dusts are ineffective in the control of the disease, particularly in orchards in localities where the disease is difficult to control. Thirteen different fungicidal dusts were used in single and multiple applications throughout the susceptible period, but none were found equal to a single application of liquid Bordeaux under similar conditions. Generally the results obtained from the dusts were very poor from both the relative and practical standpoints.

## INTRODUCTORY

### THE DISEASE: ITS CHARACTERISTICS AND ITS CAUSE

Monilia blossom blight (brown rot) is due to the attack of a fungus of the genus *Sclerotinia*.

This fungus has two reproductive forms, the imperfect stage (*Monilia*) and the perfect (*Sclerotinia*). The latter stage is exceedingly rare in California, the former very common.

Monilia blossom blight never kills a tree; it is primarily a disease of the second-year or fruit wood which it attacks through the blossoms.

The severity of the attack depends on the weather. In climates favorable to the disease its severity increases yearly if not controlled.

In the spring the apricot blossoms are attacked at any time after the buds have cracked and show the folded white petals beneath the red sepals until the petals have fallen. The killed flowers remain fixed to the twigs until eventually dislodged by storms.

Fig. 1.—Apricot fruit spurs killed by Monilia blossom blight. The dead flowers do not fall off. Note the production of gum at the junction of living and dead tissue. From Bull. 326, Calif. Agr. Exp. Sta.

From the flowers the fungus passes into the spurs, killing them back as much as five inches in one week and a foot or more before it ceases to be active. Fruiting twigs may be killed back five feet by numerous infections along their entire length or by girdling from a single infection at the base.

Copious amounts of amber- or honey-colored gum are characteristically produced at the junction of the living and the dead tissue. It is harmless and being readily soluble in rain water may not always be present. (Fig. 1.)

In humid weather the dying flower parts usually become covered with fungous spores (the Monilia stage) within about twenty-four hours after infection.

Fig. 2.—Production of Monilia spores from cankers on almond twigs killed the previous spring by Monilia blossom blight. The spore pustules are recognized as roundish light-colored bodies. Natural size. From Bull. 326, Calif. Agr. Exp. Sta.

Having killed a spur the fungus becomes dormant or inactive until the following winter when it is reactivated by wet weather. Spores are produced in almost inconceivable numbers on the dead wood. (Fig. 2.) If the wood dries out, spore production ceases for the time being.

Spores are reproductive bodies. The Monilia spores are produced in chains. Hundreds, possibly thousands of these spore chains are grouped in dense clusters, visible as tiny powdery pustules or cushions on the old decayed fruits and twigs. At first the pustules are bluish- or ash-gray, becoming buff to brown as they age and dry out. When a spore is ripe it falls away from the chain, and new ones are constantly being produced from the base. (Fig. 3.)

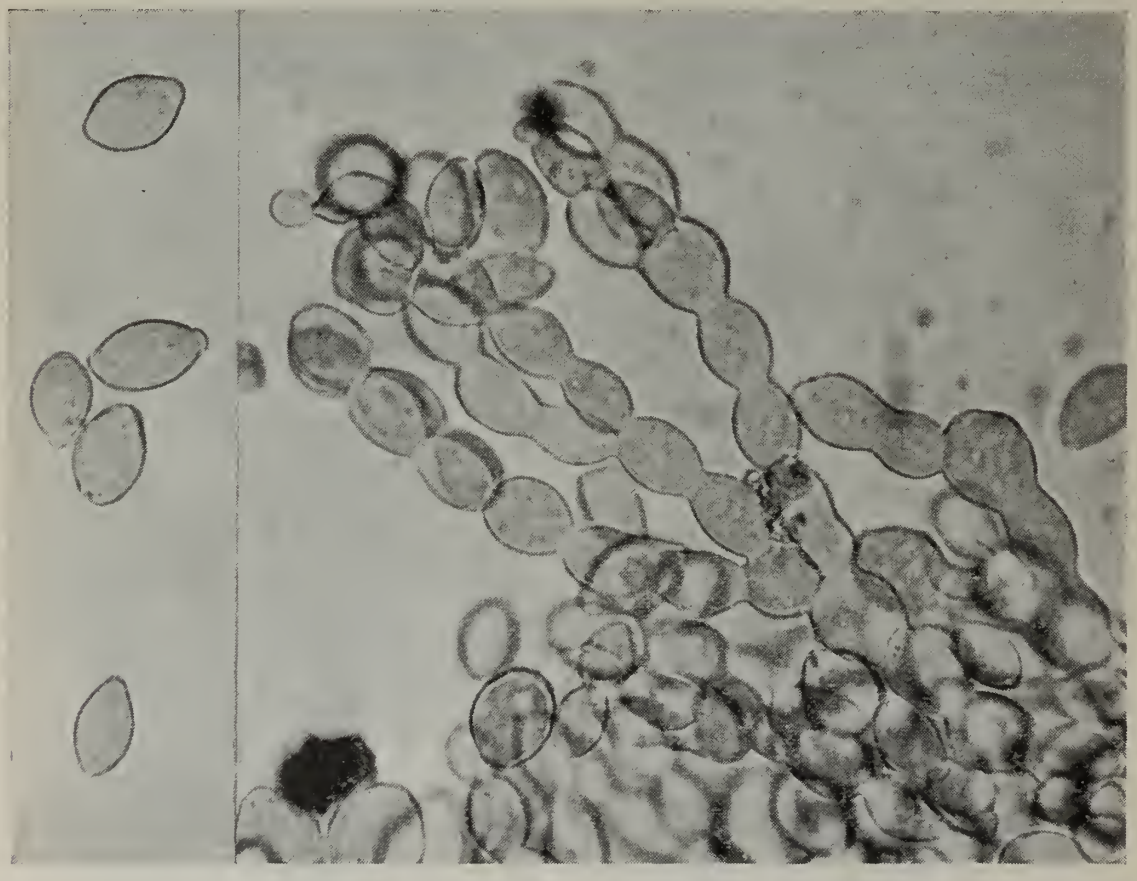

Fig. 3.—Photomicrograph of Monilia spores produced in culture on Czapeck agar.

A spore germinates if sufficient moisture is present and sends forth a fungous thread which quickly penetrates and kills the petals and reproductive flower parts, finally passing into the spur.

Large, ugly cankers may be produced in the older wood, the attack usually being made from the base of a killed spur. The cankers ordinarily are inconspicuous until the bark dries and peels away in summer revealing deep gummy lesions. These ordinarily heal over by the end of the year and cause no further trouble.

New tender foliage may be attacked in very wet weather, but the resistance of the new growth to the disease is usually marked.

Repeated efforts to induce the fungus to attack healthy bark of either first or second year wood by binding spore pustules or spore covered fruits to the twigs with moist bandages failed.

Occasionally, in very wet weather the young fruits in the jackets are attacked, but after the old flower parts have fallen away they rarely suffer much. Attacks at this stage are usually made through insect wounds and abrasions.

A rot of small green apricots produced by *Sclerotinia libertiana* Fcl., a closely related fungus, is frequently confused with brown rot.

Fig. 4—Brown Rot of ripe apricots. The disease passes from fruit to fruit in clusters, through the skin. Note enormous production of Monilia spores on the surface. Natural size. From Bull. 218, Calif. Agr. Exp. Sta.

Ripe fruit is much less resistant to brown rot. According to Cordley,[33] Smith,[19] Cooley,[69] Valleau[77] and others the fungus can penetrate the healthy skin of peaches, plums and cherries, and the same is probably true of the apricot. One diseased fruit will occasion the destruction of an entire cluster of apricots, the fungus passing through the skin of each with ease.

Fig. 5.—Apricot "mummy" produced by Brown Rot. Spore pustules of the fungus may be clearly seen on the fruit near the stem. From Bull. 326, Calif. Exp. Sta.

Once attacked, the green or ripe fruit rots quickly. A minute, circular brown spot appears which rapidly enlarges, finally enveloping the entire fruit. The common term "brown rot" is derived from the appearance of the decay of the fruit. Fungus spores are produced on the rotting fruits in enormous quantities. (Fig. 4.)

Most affected fruits fall, but some remain in the trees where they shrivel to a tough, leathery condition and as such are known as "mummies." (Fig. 5.)

From the old mummies on the ground, the so-called *apothecial* or perfect stage is produced. Hard, irregular-shaped, black bodies, somewhat resembling black rubber when fresh and frequently as large as a grain of corn, develop in the decayed fruit tissue. They are known

Fig. 6.—Prune "mummy" with apothecia of the brown rot fungus. (Courtesy C. Brooks and D. Fisher, U. S. D. A.)

as *sclerotia* and constitute a resting stage. In this form the fungus can safely withstand the cold of winter and the heat and drought of summer. In the spring, at blossom time, *apothecia* are produced from the *sclerotia*. They are little fleshy fungous bodies, trumpet- or morning glory-shaped, which consist of a stalk several millimeters to

several inches long and a cup or trumpet-shaped structure at the top, two or three millimeters to several centimeters in diameter. (Fig. 6.)

Roberts[95] and Ezekiel[96] have shown that apothecia may be produced in the spring following the decay of the fruit, although ordinarily they do not appear until the second year.

The apothecia are lined on their upper or inner surface with innumerable, minute, cylindrical sacks called *asci.* (Fig. 10.) Each *ascus* contains eight spores which are released when ripe and carried by air currents to the blossoms. The flowers are quickly attacked if

Fig. 7.—Flowers and twigs of the Japanese Quince (*Chaenomeles japonica*) attacked by Monilia blossom blight. Note heavy production of Monilia spores on the dead blossom. Twice natural size.

moisture conditions are favorable, and within a day or two the dead and dying parts become covered with masses of spores of the chain type already described. Thus the cycle is complete.

The apothecial stage is the great source of trouble in the eastern states, also in certain parts of Oregon. In California it is exceedingly rare and of no consequence in the propagation of the fungus. Also, since the Monilia stage insures abundant reproduction in the spring it is superfluous.

Pollock[84] has shown that while the mummies eventually rot away in the soil, the sclerotia may persist there for ten years and annually send up their crop of spore-bearing apothecia.

## HISTORY OF THE DISEASE

The first published account of brown rot of fruit appeared in 1796 in Europe when Persoon[1] gave the name *Torula fructigena* to a fungus which he found on decayed fruit of *Prunus domestica* (European plum), *Amygdalus persica* (peach) and *Pyrus communis* (French pear). Many investigators, including Albertini and Schweinitz,[3] Fuckel,[12] Saccardo[14] and Rabenhorst[10] have used this name. In 1801 Persoon[2] changed the name of the fungus to *Monilia fructigena* which name is still in use. In 1817 Kunze and Schmidt[4] referred the fungus to *Oidium fructigenum,* and among those who retained this name are Ehrenberg,[5] Fries,[7] Duby,[8] Cooke[13] and Smith.[17] This name, however, has now gone out of general use. In 1822 Persoon[6] renamed the fungus again, calling it *Acrosporium fructigenum,* a classification which has never been accepted by scientific writers. In 1833 Wallroth[9] referred the fungus to both *Oospora candida* and *O. fructigena,* but in 1875 von Thümen[15] changed the name to *Oidium wallrothii* and still later to *O. fructigenum.*

In 1851 Bonorden[11] described for the first time another brown rot fungus occurring "on rotting fruit" which he named *Monilia cinerea.* The differences between this fungus and the one described by Persoon were considered too meager, however, by some investigators to permit of its being regarded as a distinct species. In 1898–99 Woronin[32] proved that the two species are distinct.

In 1893 Schröter[27] referred the two species of *Monilia* to the genus Sclerotinia, being confident from his studies of them that a second reproductive form, the *apothecial* stage eventually would be discovered. In 1904 Aderhold[43] confirmed these predictions when he found the perfect stage of *Monilia fructigena* in Europe.

In the United States brown rot has been very troublesome, and for nearly half a century there has been a steady output of publications dealing with the pathological, physiological, morphological and etiological aspects of the disease and its therapeutics. The better known papers are those of Peck[16] (1881), Arthur[18] (1886), E. F. Smith,[19] Galloway[20] (1889), Humphrey[21] (1890), Smith[22] (1891), Halsted,[23] Chester,[24] Jones[25] (1892), Humphrey[26] (1893), Taft,[28] Bailey[29] (1894), Kinney,[30] Goff[31] (1987), Cordley[33] (1899), Quaintance,[34] Waugh,[35] Bioletti[36] (1900), Norton,[37] Clinton,[38] Bioletti[39] (1902), Starnes,[40] Alwood and Price,[41] Card and Sprague[42] (1903), Clinton,[44] Sheldon[45] (1905), Heald[46] (1906), Scott,[47] Faurot,[48] Stone and Monahan,[49] Kern[50] (1907), Dandeno,[51] Reade,[52] Blake[53] (1908), Pollock,[54] Scott

and Ayers[55] (1909), Lewis,[56] Pollock,[57] Scott and Ayers,[58] Stewart,[59] Scott and Quaintance[60] (1910), Scott and Quaintance[61] (1911), Demaree,[62] Whetzel[63] (1912), Cook,[64] Jehle,[65] Matheny[66] (1913), Conel,[68] Cooley,[69] Orton,[70] Jehle[71] (1914), Bailey,[72] Jackson,[73] Posey,[74] Stakman and Rose,[75] Heald,[76] Valleau,[77] Hawkins[78] (1915), Bartram,[79] Brooks and Cooley,[80] Brooks and Fisher,[81] Hessler[82] (1916), Pollock[84] (1918), Willaman,[92] Horne,[87] Willaman,[93] Howard,[89] McCubbin,[86] Cook,[90] Anderson,[94] Cook[91] (1920), Roberts,[95] Ezekiel,[96] Howard and Horne[97] (1921), Barss,[98] Ezekiel,[99] Brooks and Fisher,[100] Norton, Ezekiel and Jehle[101] (1923), Norton and Ezekiel,[102] Brooks and Fisher[103] (1924).

In 1902 Norton[37] discovered the apothecial stage of the brown rot fungus in this country and named it *Sclerotinia fructigena* because the imperfect stage occurring here was then commonly regarded as *Monilia fructigena.* Subsequent studies of this form by other investigators led to the general opinion that what Norton really found was the perfect form of *S. cinerea* and not *S. fructigena* as he supposed. Also it was concluded that *S. fructigena* never has occurred in this country and that the fungus occurring here should never have been called by any other name than *S. cinerea.* Accordingly the great majority of writers have referred to the American brown rot fungus as *Sclerotinia cinerea* until as late as 1920.

In 1920 Wormald[88] demonstrated that while *S. cinerea* of Europe and America are practically identical morphologically, biologically they may be distinguished with comparative ease and suggested the new name *S. cinerea, forma americana* for our brown rot fungus.

In 1923 Norton and Ezekiel[102] presented a paper before the American Phytopathological Society at Cincinnati confirming Wormald's work. A brief abstract of their paper appeared in Phytopathology in 1924 suggesting that the American brown rot fungus be renamed *Sclerotinia americana* Wormald, since in their opinion it can no longer be considered identical with *S. cinerea* of Europe. Whether this very recent reclassification will meet with the general approval of other investigators will depend largely to what extent Wormald's work has been confirmed by Norton and Ezekiel whose publication giving the details of their work has not yet appeared.

Posey[74] and Barss[98] believe there are two distinct forms of the brown rot fungus in Oregon, and in recent years Wormald[85] has shown that even the two accepted species of the brown rot fungus in Europe have each at least two distinct biologic strains.

Other forms of the brown rot fungus have been described, possibly the best known of which is *Sclerotinia laxa* (Ehrenb.) Ader. and Ruhl. Many investigators, however, insist it is identical with *S. cinerea.*

Possibly the first published account of the disease in California, that of Professor F. T. Bioletti[36] of the University of California, appeared in the Pacific Rural Press following a severe outbreak of the disease in ripening Moorpark apricots at Niles. He briefly discussed the cause of the disease saying, "It is particularly injurious to peaches in the eastern states and to prunes and apricots on the Pacific slope." He was fully aware that the disease also attacks the blossoms and young growth of the peach and concluded that "the same probably occurs in the case of apricots and other fruits."*

Since 1902 frequent references to brown rot may be found in the Annual Report of the California Agricultural Experiment Station.

In 1916 the California Agricultural Experiment Station undertook experimental spraying for the control of the disease. No conclusions were drawn because climatic conditions prevented an attack. In 1918 Circular 204 appeared with recommendation for the control of the disease, but investigational work was not resumed until 1920. In the meantime the annual loss in the San Francisco Bay region due to the killing of the blossoms had reached alarming proportions. Originally observed as a disease of ripening fruit, the apricot industry in the coastal regions was now menaced by the blossom blight. Because of the thoroughness and the rapidity with which the blossoms are destroyed after damp cold spells, much of the earlier Monilia blossom blight damage was mistaken for frost injury. For similar reasons many growers attributed the disease to sour sap, sour soil and other causes.

The results of the first year's experiments at the Deciduous Fruit Station are contained in Bulletin 326, and the present paper covers the experimental control work up to the present time.

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* In a recent personal interview Professor Bioletti stated that while he had never seen specimens of diseased apricot blossoms when he wrote his paper, it was common hearsay at the time that they were attacked.

## IMPORTANCE OF THE DISEASE IN CALIFORNIA

No accurate estimate of the annual loss occasioned in California by Monilia blossom blight can be given. Unquestionably the loss in fruit alone, to say nothing of the great cost of fighting the disease, has amounted to hundreds of thousands of dollars annually in the past.

Several typical examples of the destructiveness of the disease may be given: In one orchard in the Santa Clara Valley the disease was so bad in 1920 that only $750 was realized from about nine acres of large Blenheim apricot trees, of which $250 was paid to pick the occasional scattered fruits. Apricots that year brought $100 a ton. Experienced fruit buyers estimated that at the prevailing price the orchard should have produced $12,000 worth of fruit. In 1921 at Berryessa in one nine-acre orchard of large Blenheim apricot trees only one ton of fruit was picked. Before Monilia blossom blight had invaded this orchard it regularly produced upwards of ninety tons a year.

Many fine old apricot orchards have been dug up in the past five years, others have been virtually abandoned, and many hundred acres of trees have been worked over to more resistant varieties of prunes.

In addition to the very great losses occasioned by the killing of the blossoms, large losses have been sustained by the rotting of the ripe fruit. Discussion of this phase of the disease is reserved for a future paper.

## Possible Reasons for the Increase of the Disease in California

Several possible reasons for the increase of the blossom blight phase of the disease in comparatively recent years may be advanced: It may be due to a change of climate. This is probably the least tenable of all hypotheses. But, if for any reason the coastal regions are damper or more foggy today than they were twenty years ago, the increase in the amount of the disease may be explained on this basis.

A second possible reason for the increase of the disease may be found in the fact that great stretches of land which once grew hay and grain are now solidly planted with apricots, thus facilitating the spread of the disease.

Possibly the most plausible reason for the increase lies in the fact that varieties more susceptible to the disease are now being grown.

Comparatively a few years ago the Moorpark was widely cultivated. Today it is virtually a thing of the past. It is an excellent eating and drying apricot, but it bears irregularly, tends to ripen unevenly, also its flat-sidedness detracts from its appearance when canned, and it "cooks up" making a cloudy syrup. It is therefore unsuited to canning purposes and has little demand. The Blenheim apricot, particularly adapted to coastal conditions, conforms more closely to canning requirements. It bears heavily and regularly, ripens evenly, also it is round and firm and does not produce a cloudy syrup when canned. The Moorpark is the most resistant and the Blenheim the most susceptible of all varieties. Similarly the Hemskirk, resembling the Moorpark in many ways is no longer planted to any extent. Other varieties, better adapted to the climate of the interior valleys, such as the Tilton are more resistant than the Blenheim, but under certain conditions they may suffer severely from the disease as is true of even the Hemskirk and Moorpark.

Still another possible reason for the increase of the disease may be that the fungus has become better adapted to the attack of the blossoms, or a new strain of the organism may have been introduced into the state. Posey[74] and Barss[98] claim to have found a new species in Oregon.

## EXPERIMENTS FOR THE CONTROL OF MONILIA BLOSSOM BLIGHT

### INTRODUCTORY STATEMENT

Since 1921 extensive experiments for the control of the disease and observations of the results obtained by private orchards with sprays have been made.

*Scope of the Experiments.*—The experiments involved the use of most of the better known liquid fungicides as well as oil emulsions, miscible oils, coal-tar derivative sprays, fungicidal dusts and a number of proprietary spray materials presumably of a fungicidal nature. About one hundred distinct treatments were tried, involving the use of these materials, separately or in combination, singly or in multiple applications.

The value of orchard sanitation as a means of fighting the disease was investigated.

The experiments were made in Santa Clara, Alameda, San Benito, Monterey and Santa Cruz counties. Duplicate experiments were also conducted by the farm advisors in most of these counties to verify the results obtained in the main experiments.

Orchards used in the experiments were of the Blenheim variety, old or fully mature, of uniform size and in a very seriously diseased condition.

*The Time the Sprays were Applied.*—The sprays were applied when the trees were fully dormant in winter, in the spring when the buds were swelling, when the trees were coming into bloom, and when the petals had fallen.

*The Number of Trees Used in the Experiments.*—Ten to thirty trees were included in each sprayed plot, except in several instances where fewer than ten trees were used. The actual number of trees used in each experiment is given in the tables. Check plots, usually consisting of ten trees each were left at suitable points in the orchards by comparison with which the relative degree control afforded by any treatment was determined.

*How the Sprays were Applied.*—Bean spray pumps and spray guns were used to apply the different sprays at a pressure of 200–300 pounds. The tanks were carefully cleansed after each treatment. Care was taken to cover all parts of the trees with as little waste as possible.

*Method of Determining Results.*—After the disease had run its course four men provided with hand tally-counting machines counted the infections that had developed in the sprayed trees and check trees. At least two counts were made from each tree by different men, and if the figures varied too greatly recounting was resorted to indefinitely until a satisfactory count was obtained. In general the counts ran very close together even in trees having several hundred or more infections. A difference of twenty in the count obtained in any tree having upward of two hundred infections was considered too great and a recount made. The counts taken on trees having little disease were usually identical or very nearly so. Only freshly killed spurs, one or more inches in length, were counted unless unmistakably specimens of Monilia blossom blight.

The average number of infections per tree was obtained by dividing the total number of infections counted in the plot by the number of trees in the plot. This method determined the degree of relative control afforded by the treatment. The degree of practical control and the ultimate success of any treatment was determined by observing

how closely the average number of infections per tree approximated a certain figure considered arbitrarily as the point of failure. Also the general effect of the treatment on the health of the trees. For instance, the degree of control, relatively speaking might be very great, but from the practical standpoint very poor. Too many infections may develop in a tree in spite of a spray to permit of even a fair-sized crop, yet when compared with unsprayed trees the control has been great. Generally speaking, any mature apricot tree of average size having one hundred killed fruit spurs is seriously diseased from the practical standpoint, and this figure was used as a basis to determine the efficacy of the spray treatments. Such a tree presents a sorry sight, and an orchard which will average one hundred infections per tree not only fails to produce a satisfactory yield, but its value is greatly depreciated.

Similarly, no treatment was considered successful which injured the trees, regardless of whether the control was good or bad. Fungicides containing sulfur were regarded as failures, therefore, as this element proved harmful to apricot trees.

*Observations Made in Private Orchards.*—Counts were made of the infections in approximately two hundred private orchards in Napa, Santa Clara, San Benito and Monterey counties in the past four years. In no instance were counts made unless the owner could give accurate data of the exact strength of spray materials used and when they were applied. A number of these orchards were sprayed under the direct supervision of the University, which in some instances also furnished the materials used. The use of brackets throughout the tables of this paper indicates that the blocks examined adjoined each other and were of the same size, age and variety.

*The Explanation of Terms.*—The following explanation of terms is given to facilitate reading the experimental data.

BORDEAUX MIXTURE.—The well-known fungicide made of copper sulfate (Bluestone) and unslaked lime. Figures are generally placed after the name of the spray to indicate the strength of the mixture; the first figure indicates the number of pounds of bluestone used, the second the number of pounds of lime and the last the number of gallons of water. Bordeaux 4–4–50 is known as "standard strength," Bordeaux 5–5–50, "winter strength" and Bordeaux 8–8–50 "double standard strength."

FUNGICIDAL DUSTS.—Powders or dusts having fungicidal properties, blown directly upon the trees with a bellows or power blower.

These materials are usually composed largely of some inactive, harmless substance known as a "filler" or "carrier" which carries the fungicide with which it is mixed to the trees. Fillers commonly used are air-slaked lime, kaolin, talc and sublimed sulfur.

Lime-Sulfur Solution 1–10 (Winter Strength).—Ordinary commercial lime-sulfur solution, 32°–34° Baumé, used at the rate of one gallon of the solution to nine gallons of water.

Self-Boiled Lime-Sulfur 8–8–50 (Standard Strength).—In this mixture the 8 pounds of superfine sulfur is partially cooked by the heat generated when the 8 ponds of unslaked lime is allowed to slake in part of the water. At the end of 5 minutes of boiling, the mixture is quickly cooled by the addition of the rest of the water.

Orchard Sanitation.—Here used, the term refers to removing and destroying all twigs, fruit spurs and mummied fruits which have been killed by the fungus and which might serve as a source of reinfection.

Dormant Spray.—One applied when the trees are wholly inactive or dormant in winter.

Delayed Dormant Spray.—One applied very early in the spring when the buds are swelling but before the red bud appears in the case of the apricot.

Red Bud Spray.—One applied after the full red bud has appeared but before the flowers are open.

Pre-Bloom Spray.—Any spray applied before the flowers open. The dormant, delayed dormant and red bud sprays are pre-bloom sprays.

Bloom Sprays.—Sprays applied as the trees are coming into bloom. A "half-bloom spray" is one applied when half the flowers are open. A "full bloom spray" is one applied when the trees are in full bloom.

Sprayed in the Jacket.—Sprayed after the bloom has passed, but before the old flower parts have fallen away.

Multiple Spraying.—The use of more than one application of spray to control fungus and insect pests.

Check Trees; Check Plot.—Untreated trees or plots of trees by comparison with which the degree of control afforded by any treatment applied under identical conditions may be determined.

## DORMANT SPRAYS

*Experimental.*—Dormant sprays were tested in 1921 in the John Fahey orchard at Sunnyvale which consists of Blenheim apricots, 25 years of age, of very uniform size and pruned in the usual way. The sprays used were Bordeaux 5–5–50 and Lime-Sulfur solution 1–10.

TABLE 1

RESULTS OBTAINED WITH DORMANT SPRAYS IN THE JOHN FAHEY ORCHARD IN 1921

| Material used | Number of trees in plot | Maximum number of infections per tree | Average number of infections per tree | Per cent of disease compared with check plot |
|---|---|---|---|---|
| Bordeaux 5–5–50 | 10 | 205 | 102 | 34.4 |
| Check plot | 10 | 414 | 296 | |
| Lime-sulfur solution 1–10 | 10 | 245 | 184 | 62.1 |

The table shows that while only 34.4 per cent as many infections developed in the plot sprayed with Bordeaux as in the unsprayed plot adjoining, the actual number of infections exceeded the number regarded arbitrarily as indicative of failure from the practical standpoint. The control with lime-sulfur was even poorer. Both treatments were regarded as failures from the practical standpoint.

A similar experiment was made in 1922 in the 22-year-old Blenheim apricot orchard at Berryessa belonging to Mrs. G. Vennum with similar results.

*Results Obtained in Private Orchards with Dormant Sprays.*—In private orchards fungicidal sprays are rarely used during the dormant period, but a few orchards were visited which had been sprayed with fungicides at winter strength during the dormant period. In these the average number of infections per tree was invariably high, and the degree of control a failure from the practical standpoint.

## DELAYED DORMANT AND RED BUD SPRAYS

*Successful Results Obtained in Private Orchards.*—In the work of Howard and Horne[97] the only control obtained was with delayed dormant or red bud sprays, either of which proved equally efficacious. Observations made in private orchards during the past four years largely confirm their work. See Table 2.

The following tables show a degree of control that was highly satisfactory from either the relative or the practical standpoint.

*Unsuccessful Results Obtained in Private Orchards.**—While a spray applied just before the blossoms open is the best, such a spray is not always successful. In badly infected orchards situated in regions normally damp during the blossoming period, either the delayed dormant or the red bud spray may fail to give the practical control sought for. See Table 3.

TABLE 2

RESULTS OBTAINED WITH DELAYED DORMANT OR RED BUD SPRAYS IN PRIVATE ORCHARDS

| Orchardist | Locality and year | Treatment | Number of *sprayed* trees. Age of trees, variety. Average number of infections. | Number of *unsprayed* trees. Age of trees, variety. Average number of infections. |
|---|---|---|---|---|
| I. Higgins | Mt. View 1922 | Bordeaux 5–6–50. Delayed Dormant. | 46 trees examined. 15-year Blenheims. 9 infections, average. | 4 trees examined. 15-year Blenheims. 94 infections, average. |
| Higgins | Mt. View, 1922 | Bordeaux 5–6–50. Delayed Dormant. | 51 trees examined. 15-year Blenheims. 7 infections, average. | |
| Malovina | | Unsprayed. | | 52 trees examined. 15-year Blenheims. 178 infections, average. |
| Churin | Mt. View, 1922 | Bordeaux 5–6–50. Red Bud spray. | 34 trees examined. 30-year Blenheims. 11 infections, average. | |
| Popovitch | | Unsprayed. | | 38 trees examined. 30-year Blenheims. 184 infections, average. |
| G. H. Bacon | Hollister, 1923 | Bordeaux 5–5–50. Red Bud cracking. | 12 trees examined. 20-year Blenheims. 7 infections, average. | 12 trees examined. 20-year Blenheims. 104 infections, average. |
| Corotto | Hollister, 1923 | Bordeaux 8–8–50. Red Bud spray. | 12 trees examined. 10-year Blenheims. 15 infections, average. | |
| Picetti | | Unsprayed. | | 12 trees examined. 10-year Blenheims. 127 infections, average. |

Although the treatments caused a large dimunition of infection, it was insufficient to have any practical value.

*Results Obtained Experimentally with Red Bud Sprays.*—Red bud sprays were tested in the John Fahey orchard in 1921. Mr. Fahey had just purchased the orchard which had received no sanitary prun-

* The badly infected condition of these orchards at the time of spraying was due to the fact that the vital importance of cleaning up the trees was then little appreciated. Most of the orchards had been pruned in the customary manner, which is often insufficient for the ultimate control of the disease.

## TABLE 3

### UNSUCCESSFUL RESULTS OBTAINED WITH SPRAYS APPLIED JUST BEFORE THE OPENING OF THE BLOSSOMS IN PRIVATE ORCHARDS

| Orchardist | Locality and year | Treatment | Number of *sprayed* trees. Age of trees. Average number of infections. | Number of *unsprayed* trees. Age of trees. Average number of infections. |
|---|---|---|---|---|
| Holmes | Berryessa, 1921 | Lime-sulfur solution 1–10. Red Bud spray. | 43 trees examined. 25 years old. 246 infections, average. | 35 trees examined. 25 years old. 311 infections, average. |
| Bache | Campbell, 1921 | Bordeaux 4–5–50. Red Bud spray. | 42 trees examined. 30 years old. 200 infections, average. | 4 trees examined. 30 years old. 536 infections, average. |
| Vennum | Berryessa, 1921 | Bordeaux 4–5–50. Red Bud spray. | 36 trees examined. 22 years old. 168 infections, average. | 35 trees examined. 22 years old. 180 infections, average. |
| Flickinger | Berryessa, 1921 | Bordeaux 4–4–50. Red Bud spray. | 49 trees examined. 20 years old. 121infections, average. | 49 trees examined. 20 years old. 135 infections, average. |
| Jensen* | Hollister, 1922 | Bordeaux 5–5–50. Red Bud cracking. | 6 trees examined. 25 years old. 223 infections, average. | |
| | | "Buggo" Crude Oil Emulsion 30–200. Red Bud cracking. | 6 trees examined. 25 years old. 373 infections, average. | |
| | | Check plot. | | 6 trees examined. 25 years old. 473 infections, average. |
| | | Dry Lime-sulfur 10–40. Red Bud cracking. | 6 trees examined. 25 years old. 401 infections, average. | |
| | | Bordeaux 5–5–50. Red Bud cracking (duplicate). | 6 trees examined. 25 years old. 281 infections, average. | |
| King | Hollister, 1923 | Bordeaux 6–6–50. Red Bud spray. | 9 trees examined. 11 years old. 348 infections. | |
| Lewis | | Unsprayed. | | 9 trees examined. 10 years old. 1,723 infections, average. |
| Renz† | Hollister, 1923 | Bordeaux 7–8–50. Red Bud spray. | 10 trees examined. 17 years old. 123 infections. | |
| Hamilton | | Unsprayed. | | 10 trees examined. 30 years old. 1,001 infections, average. |

* Figures compiled from demonstration plots of Mr. W. J. Tocher, Farm Advisor, San Benito County.

† Renz's trees though younger than Hamiltons were equally large.

ing, and it contained therefore much infective material. Damp weather prevailed at times during the blossoming period. In those parts of the orchard where the disease had been the worst, Bordeaux gave the best results. See Table 4.

These results were of no practical value. In all cases the infections were greatly in excess of the number regarded as indicative of failure. This failure was in part due to the condition of the trees.

TABLE 4

RESULTS OBTAINED WITH SINGLE RED BUD SPRAYS IN THE JOHN FAHEY ORCHARD IN 1921

| Spray materials used | Number of trees examined | Average number of infections |
|---|---|---|
| Bordeaux 4–5–50 plus Dormant Soluble Oil (a miscible oil) 5–200 | 27 | 283 |
| Bordeaux 4–5–50 | 11 | 264 |
| Bordeaux 4–5–50 (duplicate) | 21 | 229 |

*The Most Favorable Period for Securing Good Results with One Spray.*—The best results with single sprays are obtained at the delayed dormant or the red bud stage, and the nearer the buds are to breaking and to showing the folded white petals beneath the red sepals, the better the control.

In 1921 Mr. Chappel near Sunnyvale sprayed his orchard in the red bud stage with Bordeaux 30–30–200. In a block of 42 trees on a strip of gravelly soil where most of the buds showed the white of the petals, the average number of infections was 18 to the tree. In a near-by block of 122 trees on a heavier soil, where the buds were much less advanced, the average number of infections was 103. The development of the buds is earlier in light, gravelly soils than on heavy, clay soils.

Later Mr. Chappel sprayed a neighboring orchard belonging to Mr. McDaniel. The soil here was also heavy, but the buds somewhat more advanced. In a block of 84 trees the average number of infections was 43.

The general orchard conditions in the three cases were the same. The degree of control therefore was in proportion to the nearness of the buds to the point of breaking.

Similar instances have been observed repeatedly.

Fig. 8.—The best control of Monilia blossom blight of apricots obtainable with any one spray is secured at the time when the buds are cracking, showing the folded white petals beneath the red sepals, as shown here in the center twig.

## BLOOM SPRAYS

*Experimental.*—Extensive experiments were made at Hayward in 1923 and at Hollister in 1924 with sprays applied at various times during the bloom. In both years extremely dry weather prevailed in both districts and no conclusions could be drawn, as the disease did not appear.

*Results Obtained with Full Bloom Sprays in Private Orchards.*—Observations made in private orchards during the past four years show that sprays applied during the full bloom have little practical value, although at times the decrease of infections may be great, just as in the case of pre-bloom sprays.

TABLE 5

TYPICAL RESULTS OBTAINED IN PRIVATE ORCHARDS WITH FULL BLOOM SPRAYS

| Orchardist | Locality and year | Treatment | Number of *sprayed* trees. Age and variety. Average number of infections. | Number of *unsprayed* trees. Age and variety. Average number of infections. |
|---|---|---|---|---|
| Butts * | Campbell, 1921 | Bordeaux 30–30–200. | 33 trees examined. 35-year Hemskirks. 129 infections, average. | 2 trees examined. Small Hemskirks. 487 infections, average. |
| Lester * | Campbell, 1921 | Bordeaux 30–30–200. | 72 trees examined. 25-year Blenheims. 178 infections, average. | 4 trees examined. 8-10-year Blenheims. 360 infections, average |
| A. DiFiori | San Jose, 1921 | Bordeaux 25–25–200. | 42 trees examined. Old Blenheims. 114 infections, average. | |
| Huff | Mt. View, 1922 | Bordeaux 4–4–50. | 20 trees examined. 15-year Blenheims. 257 infections, average. | 18 trees examined. 15-year Blenheims. 351 infections, average. |
| Hitchings | Aromas, 1924 | Bordeaux 30–32–200. | 10 trees examined. 30-year Blenheims. 131 infections, average. | |

* The check trees in the Butts and Lester orchards were distinctly smaller than the sprayed trees. There can be no doubt, therefore, that the spray helped a little considering the excessively high counts in the smaller trees.

In every orchard listed above the trees showed an excessive number of infections, and the treatments must be regarded as of no practical value.

*Spraying Before the Full Bloom; Results Obtained in Private Orchards.*—Observations show that sprays applied when the trees are half or two-thirds in bloom are ordinarily useless. In fact, the longer

Fig. 9.—Apricots sprayed in full bloom, too late for control of brown rot.

spraying is delayed after the flowers start to open, the greater the failure is apt to be, since fogs, dew or rain wetting the open blossoms facilitate the attack of the fungus.

TABLE 6

RESULTS OBTAINED IN PRIVATE ORCHARDS WITH SPRAYS APPLIED WHEN ONE-HALF OR TWO-THIRDS OF THE BLOSSOMS WERE OPEN

| Orchardist | Locality and year | Treatment | Number of *sprayed* trees. Age and variety. Average number of infections. | Number of *unsprayed* trees. Age and variety. Average number of infections. |
|---|---|---|---|---|
| Cinciamilla | San Jose, 1921 | Bordeaux 30–30–200. $^2/_3$ bloom. | 29 trees examined. 32-year Blenheims. 282 infections, average. | |
| Lowry | Centerville, 1922 | Bordeaux 5–5–50. ½ bloom. | 25 trees examined. 25-year Blenheims. 318 infections, average. | 10 trees examined. 25-year Blenheims. 324 infections, average. |
| Love | Aromas, 1922 | Bordeaux 5–5–50. ½ bloom. | 45 trees examined. 8-year Blenheims. 128 infections, average. | 14 trees examined. 8-year Blenheims. 267 infections, average. |
| Butts | Campbell, 1922 | Bordeaux 5–5–50. ½ bloom. | 9 trees examined. 35-year Hemskirks. 158 infections, average. | 2 trees examined.* 35-year Hemskirks. 1,377 infections, average. |
| Kelly | Hollister, 1923 | Bordeaux 8–8–50. ½ bloom. | 12 trees examined. 12-year Blenheims. 96 infections, average. | 12 trees examined. 12-year Blenheims. 281 infections, average. |
| Nicholson | Aromas, 1924 | Bordeaux 7–7–50. ½ bloom. | 10 trees examined. 38-year Early Golden. 419 infections, average. | 5 trees examined. 38-year Early Golden. 555 infections, average. |

* The two check trees in this orchard were not pruned. The excessively great number of infections was made possible, no doubt, by the presence of so much infectious material left behind in the trees.

Regardless of the stage of the bloom, the number of infections was very great, and no practical control was obtained.

## MULTIPLE SPRAYING

All sprays diminish infection regardless of the time of their application, the best results being obtained just before the flowers open. The use of repeated or multiple sprays throughout the susceptible period is discussed here.

Multiple spraying for disease and insect control is not new to California. The control of thrips, red spider, codlin moth, pear scab and peach blight frequently require more than one spray. Apple growers frequently spray as many as eight times for the control of codlin moth alone.

*Multiple Spraying in the Pre-Bloom Period.*—Table 2 shows that under certain conditions one spray applied just before the blossoms open may control the disease. It is of interest to determine whether several sprays applied in the pre-bloom period can be relied upon regularly to control the disease. It seems improbable because the

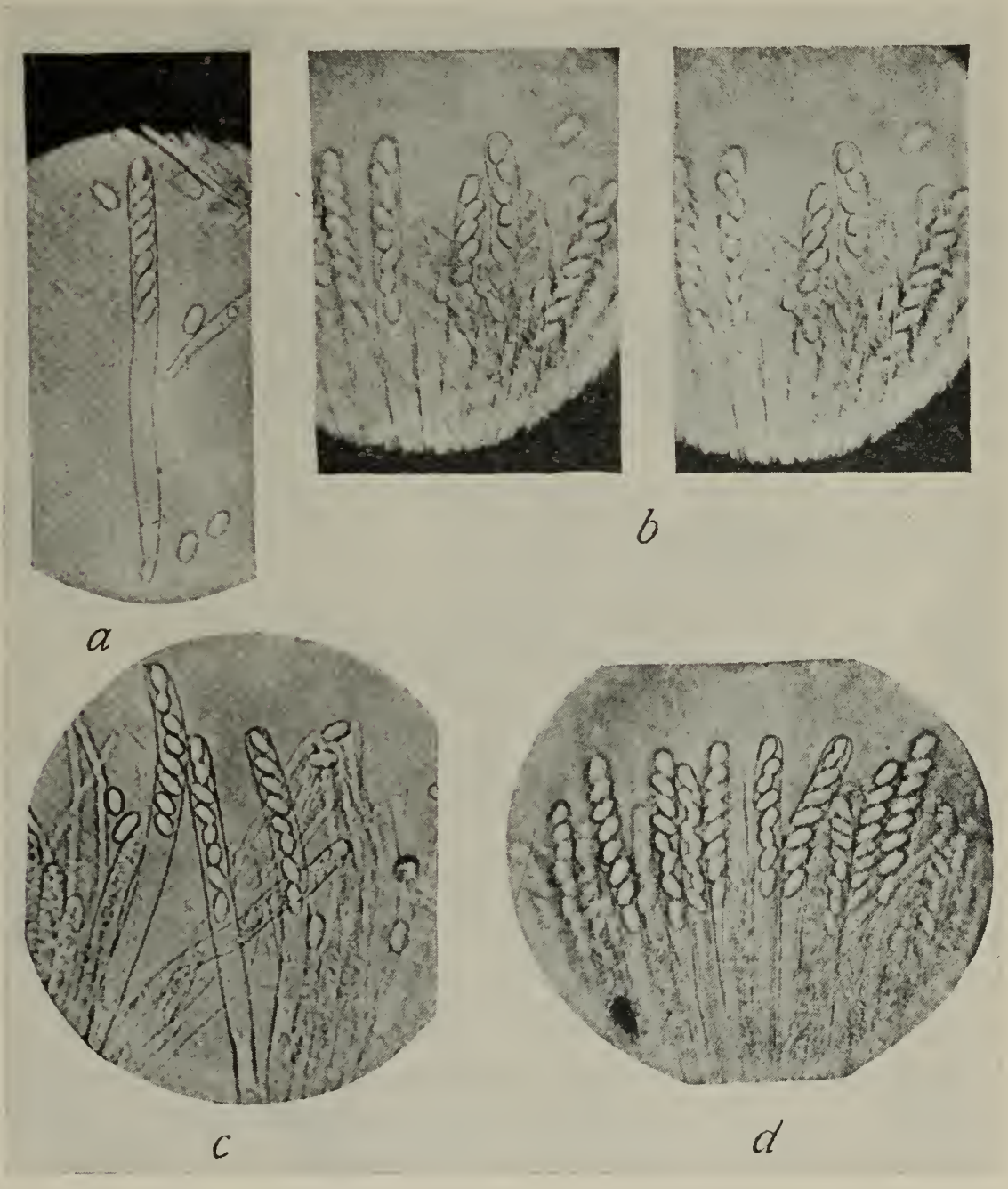


Fig. 10.—Photomicrograph of asci and ascopores of brown rot fungus (copied from Matheny).

several sprayings are confined to a period when the disease is unable or little likely to make its attack, and no spray reaches the delicate petals or reproductive parts of the flowers later to be exposed. Even assuming sprays applied in the pre-bloom to have killed all the spores in the trees, there is nothing to prevent fresh spores being blown in from outside sources to attack the flowers as they open.

In 1921 extensive experiments with multiple sprays applied in the pre-bloom were made in the John Fahey orchard at Sunnyvale.

TABLE 7

RESULTS OBTAINED WITH MULTIPLE SPRAYS APPLIED IN THE PRE-BLOOM PERIOD IN THE JOHN FAHEY ORCHARD AT SUNNYVALE

| Treatment | Number of trees in plot | Average number of infections per tree |
|---|---|---|
| Bordeaux 4–5–50. Delayed Dormant<br>Bordeaux 4–5–50. Red Bud | 7 | 207 |
| Lime-sulfur solution 1–10. Dormant<br>Bordeaux 4–5–50. Delayed Dormant<br>Bordeaux 4–5–50. Red Bud | 8 | 101 |
| Self-boiled Lime-sulfur 8–8–50. Delayed Dormant<br>Self-boiled Lime-sulfur 8–8–50. Red Bud | 8 | 190 |
| Lime-sulphur solution 1–10. Dormant<br>Self-boiled Lime-sulfur 8–8–50. Delayed Dormant<br>Self-boiled Lime-sulfur 8–8–50. Red Bud | 10 | 187 |
| Bordeaux 5–5–50. Dormant<br>"Ortho" crude oil emulsion 15–200 plus lime-sulfur solution 1–10. Red Bud | 5 | 117 |
| Lime-sulfur solution 1–10. Dormant<br>"Ortho" crude oil emulsion 15–200 plus lime-sulfur solution 1–10. Red Bud | 5 | 358 |
| Bordeaux 5–5–50. Dormant<br>Bordeaux 4–5–50 plus "Dormant Soluble Oil" 5–200 (a miscible oil) Red Bud | 5 | 165 |
| Lime-sulfur solution 1–10. Dormant<br>Bordeaux 4–5–50 plus "Dormant Soluble Oil" 5–200 (a miscible oil) Red Bud | 5 | 217 |

The results of these experiments prove that in unsanitary orchards in localities normally damp during the blossoming period two or more sprays applied in the pre-bloom period may fail to give the practical control sought.

*Multiple Spraying Throughout the Susceptible Period of the Blossoms.*—Multiple spraying throughout the susceptible period was tested in 1922 in the G. Vennum orchard at Berryessa, in the H. Owen orchard at Hayward in 1923, and in the H. Smith orchard at Hollister in 1924. No definite conclusions were drawn because the disease did not appear owing to an almost unprecedented drought during the susceptible period in the last two regions in 1923 and 1924, and because the Vennum orchard failed to bloom properly in 1922. Duplicate experiments conducted by farm advisors in other localities normally damp those years furnished much valuable data as did observations made in private orchards. See Table 8.

TABLE 8

RESULTS OBTAINED WITH MULTIPLE SPRAYS APPLIED DURING THE SUSCEPTIBLE PERIOD OF THE BLOSSOMS

| Orchardist. Locality and year. Age of trees and variety. | Number of trees | Treatment | Average number of infections per tree |
|---|---|---|---|
| G. Love.[1] | 14 | Unsprayed | 267 |
| Aromas, 1922. | 45 | Bordeaux 5–5–50. ½ bloom | 128 |
| 8-year Blenheims. | 56 | Bordeaux 5–5–50. 1/5 and ½ bloom | 48 |
| E. Seeley.[2] | 6 | Unsprayed | 239 |
| Aromas, 1922. | 6 | Bordeaux 5–5–50. Red Bud | 85 |
| 24-year Blenheims. | 7 | Bordeaux 5–5–50. Red Bud and Full Bloom | 12 |
| L. Carroll.[3] | 2 | Bordeaux 6–7–50. Full Bloom | 102 |
| Campbell, 1922. | 22 | Bordeaux 6–7–50. 1% bloom | 52 |
| 27-year Blenheims. | 14 | Bordeaux 6–7–50. 1% and 90% bloom | 30 |
| | 14 | Bordeaux 6–7–50. 1%; 90% bloom and petals falling | 13 |
| C. L. Chapman. | 12 | Bordeaux 7½–7½–50. Red Bud | 85 |
| Hollister, 1923. | 12 | Bordeaux 7½–7½–50. Red Bud and Full Bloom | 48 |
| 6-year Blenheims. | | | |
| F. P. Gettings.[4] | 6 | Unsprayed | 256 |
| Hollister, 1923. | 12 | Crude oil emulsion 30–200. Dormant Bordeaux 8–8–50. Red Bud | 52 |
| 13-year Blenheims. | 11 | Crude oil emulsion 30–200. Dormant Bordeaux 8–8–50. Red Bud and ½ bloom | 29 |
| | 14 | Crude oil emulsion 30–200. Dormant Bordeaux 8–8–50. Red Bud | 63 |
| | 12 | Crude oil emulsion 30–200. Dormant Bordeaux 8–8–50. Red Bud and ½ bloom | 11 |
| B. Jensen.[5] | 7 | Unsprayed | 148 |
| Hollister, 1923. | 7 | Bordeaux 8–8–50. Red Bud | 61 |
| 29-year Blenheims. | 14 | Bordeaux 8–8–50. Red Bud and 1/3 bloom | 40 |

[1] Demonstration plots of Mr. T. C. Mayhew, Farm Advisor, Monterey County.

[2] Demonstration plots of Mr. T. C. Mayhew, Farm Advisor, Monterey County.

[3] These different blocks while not immediately adjoining were very close to one another in the same orchard and subject to identical conditions.

[4] The block of unsprayed trees in this orchard did not immediately adjoin the sprayed plots but was very close and subject to identical conditions.

[5] Demonstration plots of Mr. W. J. Tocher, Farm Advisor, San Benito County.

The above table shows a control of the disease proportional to the number of sprays applied during the susceptible period of the blossoms.

The use of multiple sprays throughout the susceptible period of the blossoms starting with the red bud spray, which is absolutely indispensible, and ending with the full bloom or even a little later when the petals have been shed is the only method likely to secure practical results in badly infected orchards situated in localities normally damp during the blossoming period. The method is logical since it destroys the greater part of the accumulation of spores in the trees, and it insures protection to all parts of all flowers as they continue to be exposed.

## DISCUSSION

*Reasons for Failure of Single Sprays to Control the Disease.*—The possible reasons for failure of single sprays applied during the red bud stage, the period most likely to secure good results, are many: careless or hurried spraying, weak or unsuitable fungicides, lack of orchard sanitation and other factors might easily lead to failure. These factors can be corrected.

A factor that cannot be corrected, and which frequently renders control difficult is the relatively long susceptible period of the blossoms. The blossoming period may last for weeks with favorable temperature.

The disease rarely attacks the tight red buds and then chiefly through insect wounds and abrasions. Clusters of buds may die as the result of the infection of the spur through wounds or of a single infected early blossom, but this is not a direct attack on the unopened buds. As soon as the petals show, however, the blossoms may be destroyed.

A spray applied just before the red buds open gives the best results because it destroys most of the spores that have been produced in the trees. Unfortunately the spray does not kill the fungus living in the dead twigs and mummies left in the trees. Many other investigators including Bourcart[67] who quotes the observations of Prilleux (p. 237) and von Tubeuf (p. 259) have noted this. Also if moisture conditions continue favorable, fresh spores will be produced in spite of the presence of the fungicide. Then again, the pustules are very dusty or powdery with spores which causes the spray to be shed off without wetting them. Also, much dead wood remains untouched even in well sprayed trees, and upon it the fungus may fruit unhampered. Lastly, a spray applied to the red buds, only directly protects the red sepals. These curl back and under as the petals and reproductive parts are exposed. The latter having no fungicide upon them are open to attack from spores blown in from outside sources or those produced in the trees themselves.

*Reasons for the Failure of Dormant Sprays to Control the Disease.* Dormant sprays are usually very ineffective, not only for the reasons given, but because much of the spray is washed off before the susceptible arrives.

*Reasons for the Failure of Full Bloom Sprays to Control the Disease.*—Such sprays ordinarily fail because much infection has already taken place before the sprays are applied. If by any chance

the long period between the time when the first blossoms show and the full bloom when the spray is applied be characterized by clear days and dry nights the spores will not germinate and there will be no disease. Such an almost unprecedented case as this occurred in certain parts of Santa Clara, Alameda and San Benito counties in 1923 and 1924. Under such conditions the disease did not appear even in those orchards which had suffered the worst in other years.

*Conditions under which Red Bud Sprays Succeed.*—In dry localities where the climatic conditions are unfavorable to the ready production of spores, a single red bud spray is frequently effective. It may be sufficient even in damp localities in dry seasons or in any season if the sources of infection are reduced by thoroughly cleaning up of the orchard.

*Reasons for the Success of the Multiple Spray Treatment.*—In localities normally very damp during the susceptible period, and in badly infected orchards, the multiple spray method gives adequate protection to all parts of all flowers as they open day after day. Moreover, each spray destroys spores which escaped the earlier sprays, and destroys many of the spores produced after the last spraying.

## ORCHARD SANITATION

### The Relation of Careful Pruning to Spraying in the Control of the Disease

Experiments have shown a direct relationship between the control obtained with sprays and the amount of infectious material left in the trees.

In 1921 all the old twigs and mummies were pruned from seven mature Blenheim apricot trees in Mr. Morgan's orchard at Mountain View. Trees adjoining were pruned in the ordinary manner. The trees in both blocks were given a red bud spray of lime-sulfur solution 1–10. All other conditions were equal. The results are shown in Table 9.

TABLE 9

| Kind of pruning | Row number | Number of trees | Average number of infections per tree |
|---|---|---|---|
| Pruned carefully | 1 and 2 | 7 | 45 |
| Pruned in the usual way | 3 | 4 | 115 |
| | 4 | 9 | 135 |
| | 5 | 9 | 134 |

About three times as much disease developed in the trees pruned in the ordinary manner as in those pruned with care.

In 1922, similar experiments were conducted in two blocks of 6-year-old Blenheim trees in the orchard of Mrs. G. Vennum of Berryessa. The trees were sprayed with Bordeaux 7½–7½–50 when the red buds were cracking. See Table 10.

TABLE 10

| Number of trees | *Carefully pruned* Average number of infections | *Usual* pruning Average number of infections |
|---|---|---|
| Block 1: | | |
| 34 | 15 | ..... |
| 37 | ..... | 30 |
| Block 2: | | |
| 31 | 30 | ..... |
| 140 | ..... | 42 |

### Ordinary Pruning Better than No Pruning

Orchards were visited in which some of the sprayed trees were not pruned. Results obtained in the Freese orchard in 1921 are typical for such treatment. See Table 11.

TABLE 11

| Orchardist Locality and year Age and variety | Number of trees examined | Treatment | *Pruned* trees | *Unpruned* trees |
|---|---|---|---|---|
| A. F. Freese. | 63 | Dry Lime-sulfur 11½ lbs.–50 gals. | | |
| Campbell, 1921. | | Red Bud Spray | 206 | |
| 25-year Blenheims. | 35 | Dry Lime-sulfur 11½ lbs.–50 gals. | | |
| | | Red Bud Spray | | 390 |
| | 2 | Unsprayed * | | 707 |

* The unsprayed trees did not immediately adjoin the sprayed plots but were located in the same orchard close by and subject to similar conditions.

Neither of the treatments was sufficiently effective. The figures show, however, that in badly infected orchards in seasons favorable to the development of the fungus, ordinary pruning followed by a red but spray may not be sufficient to control the disease, but it tends to lessen the amount of infection.

Under certain conditions careful pruning may equal the red bud spray in the control of the disease. At Mountain View the old Blenheim apricot orchards of Messrs. Morgan and Fagundes adjoin. The general conditions are identical. In 1922 Mr. Morgan pruned his trees in the usual manner and sprayed with Bordeaux 5–5–50 in the red bud stage. Mr. Fagundes did not spray but pruned his trees very carefully. See Table 12.

Growers should not conclude that extra careful pruning may be consistently substituted for spraying. Both are vital in the eventual control of the disease. Had Mr. Fagundes sprayed as well as pruned in the manner that he did, a much lower count probably would have obtained in his orchard.

Wormald[83] of England, discouraged because the sprays neither kill the fungus within the wood nor even prevent its fructification on the blighted twigs and mummies, and because liquid fungicides do not adhere to the spore pustules on account of their dusty nature states: "At present fruit growers are strongly advised not to attempt to control this disease by spraying as they are extremely likely to waste their time and money. It has been found that washes generally used for checking the spread of the disease, for instance, lime sulfur and Bordeaux mixture, are useless as they fail to wet the pustules."

TABLE 12

| Orchardist | Number of trees examined | *Sprayed* but not pruned Average number of infections | *Pruned* but not sprayed Average number of infections |
|---|---|---|---|
| Morgan | 16 | 62 | ..... |
| Fagundes | 16 | ..... | 60 |

Sprays may not adhere to the spore pustules, but they do adhere to the susceptible flower parts and to a large degree prevent an attack by the fungus. And sprays probably kill large numbers of spores lodged in various parts of the trees, including the fringes of hair on the bud scales, which eventually might find their way to the susceptible flower parts. Sprays have been too successful here to advise discontinuing their use. But in wet seasons when the ground is too boggy for the use of spray rigs, carefully pruned trees unquestionably will have a great advantage over trees pruned in the ordinary manner or not pruned at all.

Theoretically the removal of all blighted twigs and mummies from the tree should render unnecessary the use of sprays, since their removal removes the fungus itself. Unfortunately all orchardists are not progressive enough to do this. There always are and always will be neglected orchards to serve as foci for the dissemination of the disease. That the disease may spread from orchard to orchard is evidenced by the fact that in sprayed orchards the disease is invariably worse near seriously diseased unsprayed trees. The great preponderance of reinfection, however, must come from spores produced in the trees themselves, since in sprayed orchards the amount of disease

decreases very suddenly in trees a comparatively short distance away from the unsprayed trees. In 1922, Mr. Renz of Hollister sprayed with Bordeaux 7–8–50 in the red bud stage. His neighbor did not spray. The unsprayed trees averaged 1001 infections each in a block of ten trees. In the same number of trees immediately adjoining in the Renz orchard, the average number of infections was 123. Several rows farther away from the unsprayed trees the average was only 37, and in the rest of the orchard the count was low.

### The Practicability of Careful Pruning

Many growers, skeptical at first as to the practicability of careful pruning, now admit that it pays. In 1922 Mr. B. Jenson at Hollister, pruned his orchard in the ordinary manner and sprayed in the red bud stage with Bordeaux 5–5–50. In two blocks of trees the average number of infections was 250 and 280. The following year the orchard was pruned with great care before spraying. The counts in the same blocks averaged 61 and 65 each. Even his unsprayed trees averaged only 148 infections as compared with 473 in 1922. And 1923 was very favorable to the disease in that locality. In an adjoining orchard, unsprayed and unpruned, the average number of infections was 738. General conditions in the orchards were approximately the same.

### The Disposal of Infectious Material

Prunings should be raked up as far as possible and burned. The fungus dies out in them the second year after infection. Mummies may continue to produce spores for three years. Plowing them under destroys most of them and renders production of the apothecial form difficult for the remainder.

### Experiments to Produce the Apothecial Form

The apothecial form of the fungus is only occasionally found in California, conditions apparently not being generally favorable to its development. Approximately one thousand apricot mummies were exposed on the surface or partially buried in the ground in December, 1921. Before spring the following year they had decomposed leaving only clean seeds. No apothecia had developed up to the spring of 1924.

Ezekiel[96] found that plum mummies chilled for a time would produce apothecia within twenty-five weeks of the rotting of the fruit, cold apparently being an important factor in their production. He also found that the addition of hydrated lime to soil in which apothecia were developing prevented their maturation.

### Depleted Vigor of the Trees Conducive to Monilia Blossom Blight

Trees attacked by such diseases as sour sap, bacterial gummosis and oak root fungus disease (*Armillaria mellea*) invariably suffer the worst from Monilia blossom blight. The number of infections in limbs affected with bacterial gummosis is frequently out of all proportion to the number of infections in the rest of the tree. In Table 7 the average number of infections in one block is 358 which is considerably in excess of those in the adjoining plots. Several trees in this plot were severely diseased with bacterial gummosis, one tree having 552 infections, most of which were confined to one large limb affected with the bacterial disease.

Trees suffering from bacterial gummosis or the other diseases mentioned should be invigorated by proper treatment. Trees in a vigorous condition have a greater natural resistance to Monilia blossom blight.

### The Relation of Organic Fertilizers to the Propagation of the Brown Rot Fungus

Repeated isolations of fungi from chicken, horse and cow manures failed to yield the brown rot fungus, and repeated attempts to cultivate the organism by planting spore-covered mummies in them under field conditions or in bell jars at room temperature failed. Attempts to induce the fungus to grow either on freshly cut or decaying alfalfa or any of the commoner grasses under field conditions failed. Apparently organic fertilizers have little to do with the propagation of the fungus.

### Ornamental Plants as "Carriers" of the Brown Rot Fungus

Of many commoner ornamental plants examined, the Japanese Quince (*Chaenomales japonica*) was the only one found to suffer the attacks of the brown rot fungus, and the fact that it blooms in advance of the apricots is significant. The twigs and blossoms are quickly killed, becoming covered with dense spore masses as they die. (Fig. 8.)

The fungus from the Japanese quince readily attacks the apricot. The fungus was easily recovered from lesions produced from sixty stab-wound inoculations made with it. A similar number of checks remained sterile.

## FUNGICIDES

In the past four years approximately one hundred distinct treatments for the control of Monilia blossom blight have been tried experimentally, including the use of twenty odd different fungicides, oils, coal-tar derivative sprays, proprietary compounds and fungicidal dusts.

### Bordeaux Mixture

This fungicide has regularly proved the best for controlling the disease.

In unsanitary orchards in damp localities Bordeaux 8–8–50 gives better results than Bordeaux 4–4–50. It is not contended, however, that the stronger mixture alone will effect a control. Striking instances of control with Bordeaux 5–5–50 and 6–6–50 are given in this paper. Satisfactory control with Bordeaux 4–4–50 is very rarely obtained in unsanitary orchards in damp localities. Mr. H. Owen of Haywards sprayed his orchard twice with Bordeaux 4–4–50 in 1921 at the time most favorable for the control without even appreciable results from the practical standpoint.

Spraying experiments to determine the relative efficacy of Bordeaux 8–8–50 and 4–4–50 are not complete, but the work done thus far indicates the superiority of the stronger mixture.

One application of either Bordeaux 8–8–50 or 4–4–50 may fail to secure a practical control, but the degree of relative control will be greater with the stronger mixture. The degree of control will depend upon the care with which pruning has been done, the climate during the susceptible period, and the number of applications of spray given, if the case is serious and the first two factors are unfavorable.

Individual experience alone will determine the proper strength of Bordeaux to use in any locality. There is no advantage in using the stronger mixture if the weaker always proves satisfactory. But those growers who have had no practical results with one or more applications of Bordeaux 4–4–50 should not hesitate to increase the strength of their mixture.

There is no danger of burning either the buds or the blossoms of the apricot with a properly made Bordeaux. As many as five applications of Bordeaux 8–8–50 were tried experimentally to large blocks of trees in the H. Owen orchard at Haywards in 1923 without injury of any kind. The fruit at harvest was large, abundant and of excellent quality. In 1922 Mr. C. Frost of Berryessa sprayed four times with Bordeaux 5–5–50 starting in the red bud stage and ending in the full

bloom. The year was damp, and in the same vicinity the disease was very destructive. Yet in a block of 38 trees, typical of Mr. Frost's orchard, the average number of infections was 1. In one corner of the orchard where the disease offered its greatest resistance to control the average number of infections per tree in a block of 34 trees was only 13. The trees were seventeen years old and only ordinary pruning had been given them. Mr. Frost previously had been unable to control the disease with a single spray, and his losses were great. In one season he brought the disease under control by the multiple spray method without damage to his trees or crop.

Bordeaux 10–10–50 is not infrequently used, and one grower reported the use of Bordeaux 15–15–50 during the full bloom without damage of any kind. To use Bordeaux stronger than 8–8–50 is probably wasteful and unnecessary.

Bordeaux applied to the open blossoms does not interfere with pollination which probably takes place in the case of the apricot before the blossoms open. Experiments with new fungicides frequently led to the burning of the outer portions of the buds to such an extent that they never opened. Yet when the burning had not killed the reproductive parts within, these buds set fruit which eventually burst through the old, unopened flower parts.

### Sulfur-Containing Compounds

Sulfur or sulfur-containing compounds should not be used on apricot trees, as they are peculiarly susceptible to injury by this element.

*Lime-Sulfur Damage.*—Apricot buds and blossoms may be severely burned with lime-sulfur fungicides. High temperatures ordinarily are associated with this form of injury.

Besides burning the buds and thereby lowering the crop, lime-sulfur (and other sulfur-containing compounds) frequently poison the trees. "Sulfur poisoning" was first observed in this state on apricots by Professor R. E. Smith of this station in 1915. The injury consists of a stunting and yellowing of the new growth and foliage and the deterioration of the fruit which ripens late and is distinctly inferior in color, size and quality.

In 1921 the entire crop of apricots in the Deciduous Fruit Station orchard had been picked when the fruit in a neighboring orchard was just commencing to ripen. The fruit in the station orchard was also distinctly larger and of better quality. The station orchard had been sprayed in the red bud stage with fungicides containing no sulfur

while the neighboring orchard had been sprayed at the same time with lime-sulfur solution 1–10. All other conditions in both orchards were identical.

Lime-sulfur is rarely used now on apricots. Several years ago, when it was in general use, orchards sprayed with it could frequently be told at a glance, especially when some of the trees had been left unsprayed or else sprayed with fungicides containing no sulfur, by which a comparison could be made.

The physiological effect of sulfur on apricots is not always constant; young or old trees in a vigorous condition may withstand its poisonous effects for years. On the other hand, trees of any age may be so seriously poisoned by a single application of lime-sulfur that they fail to bloom the following year.

Lime-sulfur sprays in diluted form (summer strength) may occasion very serious injury when applied during the growing season. Several trees at the Deciduous Fruit Station were sprayed with lime-sulfur solution 1–30 when the fruit was very small. One tree was completely sprayed, another was sprayed about the lower branches only, and the third on one side only. The foliage turned yellow and the fruit sprayed with the lime-sulfur virtually ceased to grow. The unsprayed fruit developed normally. The fruit on the tree completely sprayed was undeveloped and green when the main crop in the orchard was harvested. The following year the tree did not produce a single blossom and the foliage developed very late. In 1923 the tree had recovered and set a normal crop of fruit.

*Effect of Pure Sulfur on Ripening Apricots.*—Pure sulfur applied with water may seriously injure ripening apricots. An orchard at Los Altos was sprayed with pure sulfur at the rate of 10 pounds to the 100 gallons of water on June 10. At the time of spraying the fruit was equal in size and quality to any in the adjoining orchards. At harvest time it was just commencing to color when the third or last pickings were made in the neighboring orchards. The quality and size of the fruit was so inferior that it passed at reduced price as second run fruit at the cannery. The following year the orchard failed to bloom, but in adjoining orchards there was an unusually heavy setting of fruit. All other conditions in the several orchards observed were identical. Mr. W. P. Hitchings of Aromas sprayed part of his orchard when the fruit was just commencing to turn yellow with sulfur at the rate of 11 pounds to the 150 gallons of water. Further development of the fruit ceased immediately. The sprayed fruit was picked three weeks later than the unsprayed, and it was distinctly poorer in color, quality and flavor. The foliage developed a sickly yellow color.

Howard and Horne[97] noted that self-boiled lime-sulfur applied after the fruit had set caused it to be stunted and the foliage to turn yellow.

A number of proprietary sulfur-containing compounds were used experimentally, but none of them proved as satisfactory as Bordeaux either from the standpoint of disease control or of the effects produced on the trees.

### Oil Sprays

*Value as Dormant Sprays.*—Oil sprays applied in winter for the control of insect pests frequently show fungicidal properties, but in badly diseased orchards situated in damp localities they generally fail to control Monilia blossom blight satisfactorily.

TABLE 14

Results Obtained with Dormant Oil Sprays in Private Orchards

| Orchardist | Locality and year | Treatment | Number of *sprayed* trees. Age and variety. Average number of infections. | Number of *unsprayed* trees. Age and variety. Average number of infections. |
|---|---|---|---|---|
| E. Snyder..... | Aromas, 1922 | "Ortho" crude oil emulsion 15–100. | 30 trees examined. 18-year Blenheims. 109 infections,average. | |
| | | Unsprayed. | | 6 trees examined. 18-year Blenheims. 96 infections, average. |
| L. Carroll. | San Jose, 1922 | Balfour-Guthrie "Dormant Soluble Oil (miscible oil) 10–200. | 20 trees examined. 35-year Moorparks. 235 infections, average. | |
| | | Unsprayed. | | 20 trees examined. 35-year Moorparks. 518 infections, average. |
| F. McDiarmid. | Aromas, 1922 | "Ortho" crude oil emulsion 15–100. | 30 trees examined. 16-year Blenheims. 105 infections, average. | |
| H. C. Smith. | Hollister, 1923 | "Ortho" crude oil emulsion 15–100. | 9 trees examined. 16-year Blenheims. 676 infections, average. | |
| E. F. O'Donnell. | Hollister, 1923 | "Ortho" crude oil emulsion 15–100. | 9 trees examined. 13-year Blenheims. 359 infections, average. | |
| | | Unsprayed. | | 9 trees examined. 13-year Blenheims. 832 infections, average. |

In none of these cases were results of practical value obtained.

While the degree of control afforded by dormant sprays of oil is usually very poor from the practical standpoint, occasionally it very much reduces the amount of infection. This is particularly true in

localities where the climate is not very favorable to the development of the disease. Under such conditions even a practical control may be obtained at times.

*Red Bud Oil Sprays.*—A spray applied in the spring just before the flowers appear give the best results obtainable with one spray. Oil sprays applied at this time are often extremely harmful and not to be recommended. In 1921, six plots of 10 trees each in the John Fahey orchard were sprayed in the red bud stage with crude oil emulsion ("Ortho" brand) 30–200 and distillate emulsion ("Spray-mulsion," a miscible oil) 15–200. The results were failures because the sprays either failed to check the disease or burned the buds. Burning was severest in the plots which previously had been given a dormant spray of lime-sulfur 1–10. Both of the oil sprays interfered with the pollination in all the plots. Even the flowers which escaped burning failed to set fruit. These results were confirmed by duplicate experiments made by Mr. Tocher, farm advisor at Hollister, in the B. Jensen orchard in 1922. His red bud spray of crude oil emulsion ("Buggo") 30–200 not only burned many of the buds and interfered with the pollination of the flowers, but it also failed to adequately control the disease. His unsprayed trees averaged 573 infections per tree and his sprayed trees 473.

It is believed by many that oil sprays inhibit the production of spore pustules on the blighted twigs by virtue of filling the pores and interstices of the bark with oil, thereby preventing the penetration of rain water into the wood necessary to the reactivation of the fungus. Spore production may be delayed somewhat by the coating of oil on the bark, but in wet seasons spores are eventually produced in spite of it.

The fact that oil sprays generally fail to control the disease should not prejudice growers against them or militate against their use in the field for which they are primarily intended—the control of insects.

### Fungicidal Dusts

Dusting, theoretically, is the ideal means of controlling disease and insect pests, since the equipment is light and may be used on steep hillsides or boggy ground unfavorable to the use of liquid spray rigs. Also, dusting is considerably cheaper than liquid spraying and much more quickly done.

*Experimental Dusting for the Control of the Disease.*—All the better known fungicidal dusts tested in various parts of Santa Clara County proved very unsatisfactory. Ten trees and upwards were

included in the dusted and in the check plots. The check plots always adjoined the dusted plots on the windward side. Dusting was done late at night by artificial light or before sunrise to avoid the interference of winds.

In mature trees of average size the number of infections invariably exceeded one hundred per tree. Even the degree of relative control was slight, and in some instances as many infections developed in dusted trees as in check trees. All of the materials were tried at least once in the red bud stage, and frequently as many as three dustings were given at different times during the bloom. Under similar conditions liquid sprays of standard fungicides gave far better results. The following materials were used:

1. Commercial Bordeaux Dust (General Chemical Co.).
2. Dry Lime Sulfur Dust (Sherwin-Williams Co.).
3. Lime and Sulfur Dust (25 lbs. air-slaked lime and 65 lbs. ventilated sulfur).
4. Lime and Dehydrated Copper Sulfate Dust (5% dehydrated $CuSO_4$ and 95% hydrated lime).
5. Lime and Dehydrated Copper Sulfate Dust (10% dehydrated $CuSO_4$ and 90% lime).
6. Barium-Tetra-Sulfide and Calcium Caseinate Dust (93% "B.T.S." and 7% "K-Seen") (Balbour-Guthrie Co.).
7. Kaolin and Dehydrated Copper Sulfate Dust (5% dehydrated $CuSO_4$ and 95% kaolin. Made into a paste with water, dried and ground.)
8. Kaolin and Dehydrated Copper Sulfate Dust (4% dehydrated $CuSO_4$ and 96% kaolin).
9. Lime and Dehydrated Copper Sulfate Dust (20% dehydrated $CuSO_4$ and 80% hydrated lime).
10. Lime and Dehydrated Copper Sulfate Dust (30% dehydrated $CuSO_4$ and 70% hydrated lime).
11. Copper Sulphosteatite Dust (10% dehydrated $CuSO_4$ and 90% talc made into a paste with water, dried and ground).
12. Coper Sulphosteatite Dust (20% dehydrated $CuSO_4$ and 80% talc made into a paste with water, dried and ground).
13. Talc and Copper Carbonate Dust (20% copper carbonate and 80% talc).

The last five dusts were tested in the orchards belonging to Messrs. J. Lewis and E. F. O'Donnell at Hollister in 1924. The dusted blocks contained from eighteen to twenty trees each, and each block was dusted three times, the first dusting being given when the red buds were cracking, the second when half the blossoms were out and the

third when the trees were in full bloom. Plots of fourteen to twenty trees immediately adjoining the dusted plots were sprayed once with Bordeaux 5–5–50 and 6–6–50. All other conditions were identical. From three to eight times as many infections were counted in the dusted plots as in the sprayed plots.

Ten or more duplicate experiments with the 10% dehydrated copper sulfate and lime dust were made by farm advisors in several counties. The dust was applied in single or multiple applications starting with the red bud stage and ending with the full bloom. No noteworthy control was obtained except in one instance and this in an orchard relatively free from the disease even on the check trees. In general the number of infections closely approximated those on the check trees.

*Results Obtained with Fungicidal Dusts in Private Orchards.*—At Haywards in 1922, Mr. H. Owen dusted a block of five trees six times with 10% dehydrated copper sulfate and lime dust between the red bud stage and the full bloom. The results were of no value, there being an average of 283 infections to the tree. In another part of his orchard Mr. Owen applied the same dust at least twelve times to one tree with no better results.

No fungicidal dust used in the experiments has proved as efficaceous as liquid Bordeaux, even multiple dusting failing to do the work of one liquid spray.

## WHEN TO SPRAY FOR MONILIA BLOSSOM BLIGHT CONTROL

In general it may be said that in orchards not yet seriously diseased, even if situated in regions where the disease has already proved severe in other orchards, or in orchards situated in regions where the disease never becomes a serious problem because climatic conditions are normally unfavorable to it, an application of Bordeaux 8–8–50 to the red buds or even a little later when the red buds are cracking and show the folded white petals beneath the red sepals ordinarily gives a thoroughly satisfactory control. Even Bordeaux 5–5–50 or 6–6–50 frequently give satisfactory results under these conditions.

If the size of the orchard or the spraying facilities at hand are such that all the trees cannot be covered when the red buds are cracking, a period usually of short duration, or if there is reason to believe from official weather forecastings that this period will be marked with storms, spraying operations should be advanced a little. It is better to start a little early rather than a little too late.

In badly diseased orchards where climatic conditions and the unsanitary conditions of the trees render control with a single spray difficult or uncertain, multiple spraying should be employed. Several applications of Bordeaux 8–8–50 should be given in quick succession, starting at the red bud stage and stopping when the trees are in full bloom or even a little later when the petals have been shed.

It is impossible to state just how many days apart these sprays should come because the temperature affects the rate at which the blossoms open. Nor can the exact number of applications of spray necessary to secure a practical control of the disease be given. The grower must determine this for his own individual locality. Some localities require but one spray, others two, three or more. This point will be determined largely also by the extent to which careful pruning has been practiced in the orchard.

When but two sprays are to be given they should come at the red bud stage and the first part of the bloom rather than at the last.

Multiple spraying of seriously diseased orchards should be practiced until the disease has been brought under control. Then one spray may hold the disease within the limits of practical control. Individual experience alone will determine this. It is being done today in many orchards where the disease was once a very serious problem. Certainly no attempt to revert to the single spray method or to reduce the strength of the Bordeaux should be made until a highly sanitary condition again prevails in the orchard.

## THE PREPARATION OF BORDEAUX MIXTURE

There are several ways of making Bordeaux mixture, but possibly the so-called "stock solution method" offers the greatest convenience.

### Preparation of the Stock Solutions

To make the stock solutions proceed as follows: Very carefully determine the 40-gallon level of two or more ordinary, clean, wooden, water-tight barrels and mark with copper tack or wooden peg. Empty the barrels.

Suspend 80 pounds of copper sulfate (bluestone, blue vitrol) in a clean gunny sack in one of these barrels and fill with clean water to the 40-gallon level. The water may be cold, but warm water is better, and hot water still better. If the water is very cold several days may elapse before all the bluestone is dissolved, but if sufficient hot water

is added to take off the chill, the bluestone ordinarily will dissolve during a night. In very warm water it dissolves in a few minutes. Thus 40-gallons of stock solution are made, each gallon of which contains two pounds of bluestone. Never prepare the bluestone stock solution in iron barrels as it will destroy them.

In a second barrel, the 40-gallon level of which previously has been determined, dump 80 pounds of freshly burnt lime (unslaked, lump or fat lime) and add enough water (hot or cold) to cover. Additional water must be added after the mixture starts to boil to prevent drying out and burning. But too much water must not be added at any one time or the lime may not slake properly. Stir only occasionally to permit water to reach all parts of the mass. Violent stirring tends to cool the mixture which is undesirable until the reaction is complete. After the lime is slaked add more water until the 40-gallon level is reached. Stir until all the paste or lumpy substances in the bottom of the barrel are broken up and a smooth "milk of lime" obtained. The barrel now contains 40-gallons of stock lime solution, each gallon of which contains two pounds of lime. Never use old lime that has become air-slaked and turned to powder as it contains inert chemical substances unsuited to the making of a good spray.

This constitutes the preparation of the stock solutions. They will keep indefinitely.

### How to Mix the Spray

Fill the spray tank one-half to two-thirds full of clean water, start the agitator working and pour the necessary amount of bluestone stock solution, previously determined, into the tank through the sieve. Next slowly pour in the required amount of stock lime solution through the sieve, breaking up any small pellets of lime with a flat paddle or the gloved hand. Actual grit or other impurities left behind in the sieve should be thrown away. Always thoroughly stir the stock lime solution before drawing off as it tends to settle. Fill any space that may be left in the tank with water and proceed to spray the trees. Do not stop the agitator at any time after starting to mix the spray unless absolutely necessary.

The two concentrated stock solutions should never be mixed before diluting with water, especially when the stock solutions are hot, or a poor Bordeaux will result. The cold water placed in the tank first will sufficiently cool and dilute freshly made stock solutions to prevent undesirable reactions from taking place. Also the bluestone stock solution should be added to the water first, and the lime last.

An example of how the stock solutions are used in actual practice may be given: To make a 200-gallon tank of Bordeaux 8–8–50, sixteen gallons of bluestone stock solution and sixteen gallons of the lime stock solution should be added in the way described and the tank filled to the 200-gallon level, as in Bordeaux 8–8–50, each 50 gallons contains 8 pounds of bluestone, 200 gallons requires 32 pounds. Since each gallon of stock solution contains 2 pounds of bluestone, 16 gallons of the stock solution will supply the requisite 32 pounds. The same is true of the stock lime solution.

Some growers prefer to make their stock solutions of lime and bluestone in a one-to-one ratio instead of in the two-to-one ratio, that is by dissolving 1 pound of bluestone or 1 pound of the lime to each gallon of solution instead of 2 pounds. There is no objection to this method except that it requires twice as many barrels to hold the stock solutions.

A three-to-one ratio bluestone stock solution may be made with very hot water, but it must be used up before it has cooled, because when cold the solution becomes supersaturated and some of the bluestone will settle out, thus upsetting the ratio. A three-to-one stock lime solution is impractical as the mixture is too thick and plaster-like to be handled easily.

While stock solutions once prepared keep indefinitely, the spray made from them should be used at once. The best adhesive and fungicidal properties are always obtained when the spray is freshly prepared.

The level of any stock solution left over at the end of the spray season should be marked in the barrel with a copper tack or wooden peg in order that the water lost by evaporation may be replaced with accuracy before using next year.

### Commercially Prepared Bordeaux Sprays

Home-made Bordeaux mixture is much cheaper than any of the commercial products on the market today and, when properly prepared, is equal to any and superior to most of them in its adhesive and fungicidal properties. Growers are therefore urged to familiarize themselves with the preparation of this well known spray.

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